Fleet Readiness Centers

24 JULY 2014

Presented to:

NAVAIR Additive Manufacturing INDUSTRY DAY

Presented by:

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Fleet Readiness Centers

COMFRC – Delivering Best Value to the Fleet

VISION

To be the provider of choice for aviation Maintenance, Repair and Overhaul capabilities and services

MISSION

To produce quality airframes, engines, components, and support equipment, and provide services that meet the Naval Aviation Enterprise's aircraft ready for tasking goals with improved effectiveness and efficiency. (Best Value)

FRC Locations

As of 31 March 2014

COMFRC HQ
NAS PATUXENT RIVER, MD

FRC NORTHWEST
NAS WHIDBEY ISLAND, WA

FRC WEST
NAS LEMOORE, CA

FRC SOUTHWEST
NAS NORTH ISLAND, CA

FRC WESTPAC
NAF ATSUGI, JAPAN

FRC ASE
SOLOMON'S ISLAND, MD

FRC MID-ATLANTIC
NAS OCEANA, VA

FRC EAST
MCAS CHERRY POINT, NC

FRC SOUTHEAST
NAS JACKSONVILLE, FL

Fleet Readiness Centers

Present & Future Capabilities

Advanced Manufacturing Technologies

- 3D Model Based Environment
- Digital data to shop floor
- Advanced machining technologies
- Model based instructions
- Reverse engineering

Additive Manufacturing Repair

- Laser and EB processes to repair aerospace components
  - Bearing Journals
  - Drive Shafts
  - Compressor Blades
- Cold Spray

Enterprise

- Software & Connectivity

Additive Manufacturing

- Tooling Using Additive Manufacturing
  - Small to large build volumes
  - New materials
  - Sheet metal forming tools
  - Composite tooling
    - Autoclave
    - Out of Autoclave
    - Reversal tools for Autoclave
- Support Equipment
  - Jigs, assembly & positioning fixtures
- Additive Manufacture of Aircraft Components
  - Flight critical, non-flight critical
  - Metals & polymers

Fleet Readiness Centers

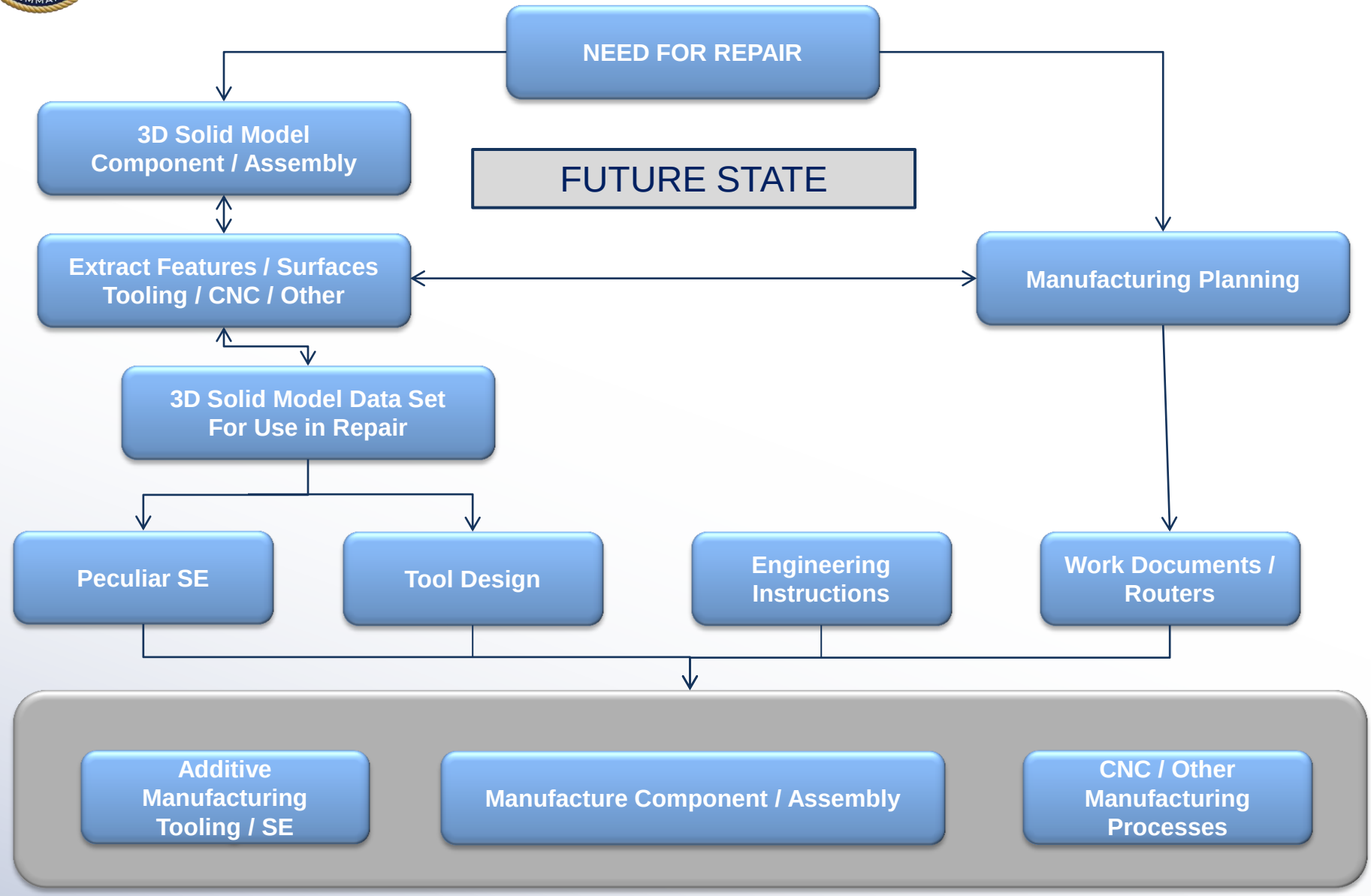
COMFRC AM EQUIPMENT IN USE

Department	Activity	Activity	Location	State	Company	Model	Process	Materials
DoD	NAVAIR	FRC East	MCAS Cherry Point	NC	Stratasys	Fortus 900mc	Fused Deposition Modeling	ABS, PC, Ultem, PPSF
DoD	NAVAIR	FRC East	MCAS Cherry Point	NC	Stratasys	Dimension SST	Fused Deposition Modeling	ABS
DoD	NAVAIR	FRC East	MCAS Cherry Point	NC	Stratasys	Fortus 400mc	Fused Deposition Modeling	ABS, PC, Ultem, PPSF
DoD	NAVAIR	FRC Southeast	NAS Jacksonville	FL	Z-Corp	Spectrum Z510	Jetted Binder	Zp150 Powder, Zb60 Binder
DoD	NAVAIR	FRC Southeast	NAS Jacksonville	FL	Stratasys	Fortus 400mc	Fused Deposition Modeling	ABS, PC, Ultem, PPSF
DoD	NAVAIR	FRC Southwest	NAS North Island	CA	3D Systems	iPro 8000	StereoLithography	Accura 25
DoD	NAVAIR	FRC Southwest	NAS North Island	CA	3D Systems	sPro 60 HD	Selective Laser Sintering	Duraform PA
DoD	NAVAIR	FRC Southwest	NAS North Island	CA	Stratasys	Dimension SST	Fused Deposition Modeling	ABS
DoD	NAVAIR	FRC Southwest	NAS North Island	CA	Stratasys	Fortus 400mc	Fused Deposition Modeling	Ultem, PC

Additive Manufacturing

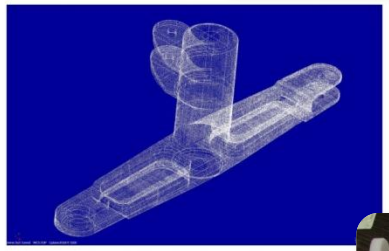
- **AM begins with 3D Digital Data**
  - 3D CAD solid modeling software
    - CATIA
    - PTC CREO
    - SolidEdge
    - SolidWorks
    - Others
  - 3D scan of part surfaces
    - Contact
      - CMM / FARO Arm
    - Non-contact
      - Laser / light scanning
    - Transform 3D scanned data
      - Refine point cloud
      - Surfaces, polygon and native CAD models

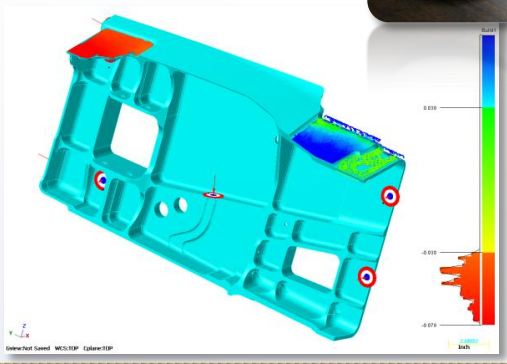
3D Solid Model Data Process

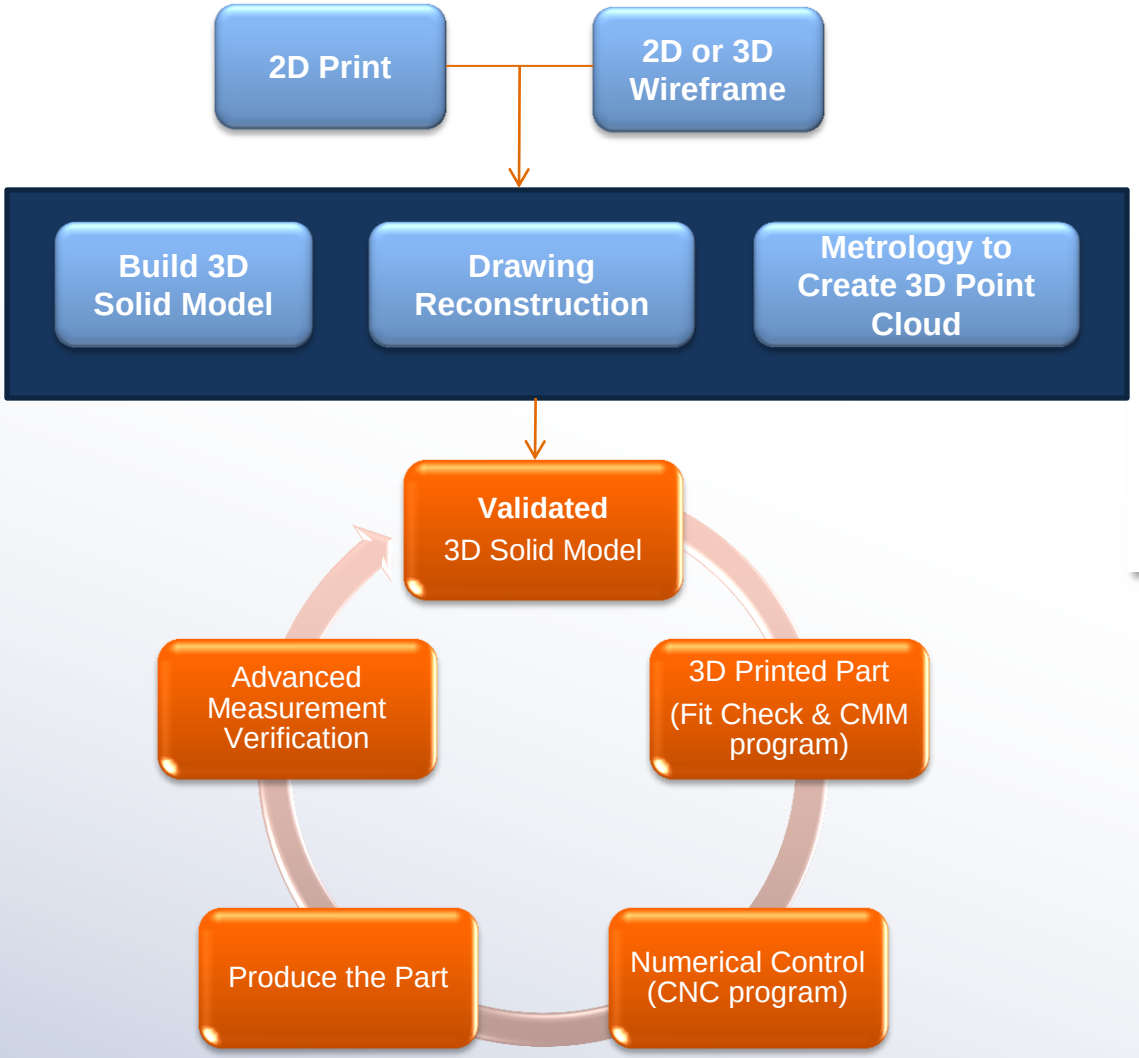


2D to 3D Model Process (Legacy)

Manufacturing Model Management System (3MS)*







*FRC-SW

No Digital Data Process (Legacy)

Manual Methods to Capture Part Geometry

Replicate Features Using Fiberglass Splash

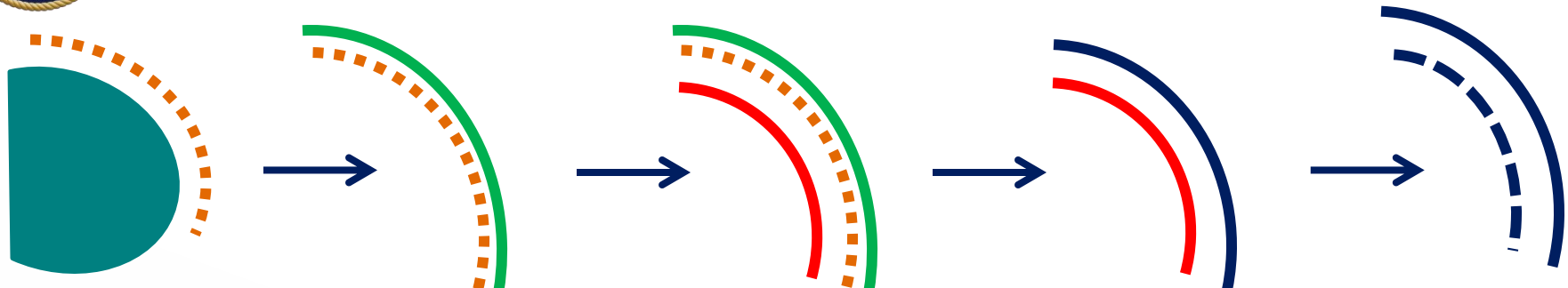
Reinforce Splash with Backing Material

Reverse Geometry Female to Male Male to Female

Cast Final Tool from Reversal

Use Tool to Produce End Use Part(s)

No Digital Data Process (Legacy)



Splash to Capture Part Geometry

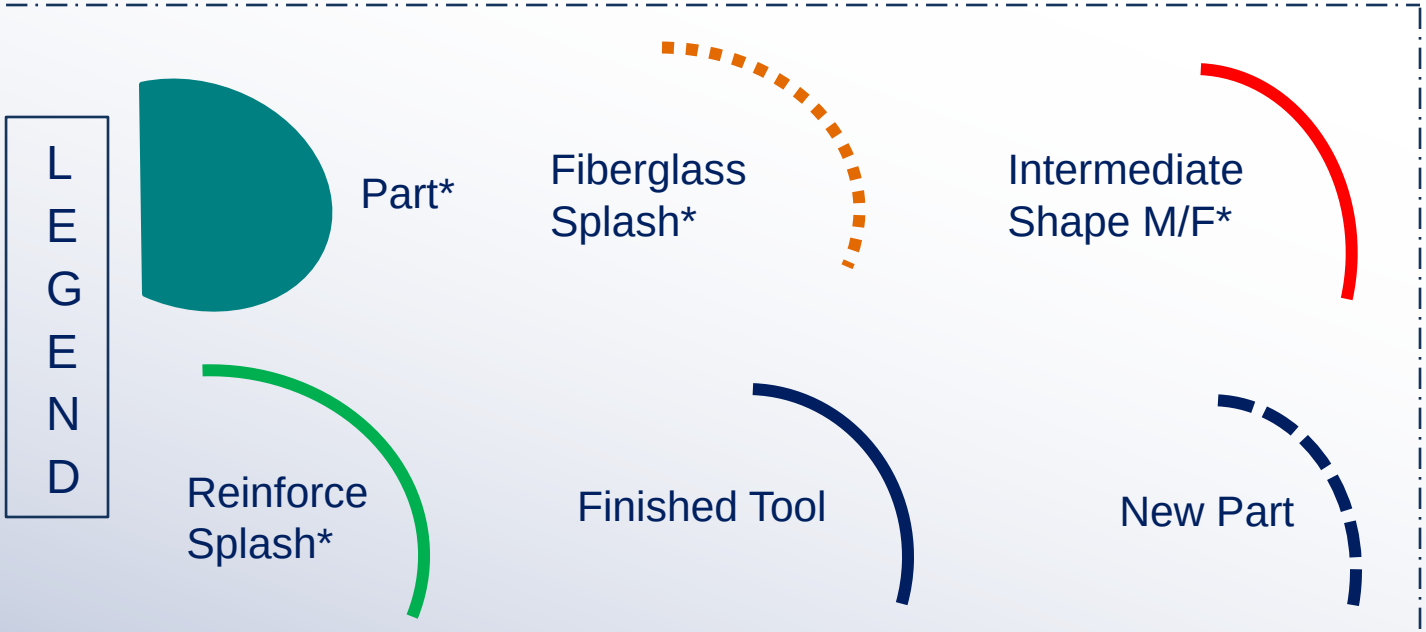
Reinforce Splash

Reverse Geometry

Create Tool

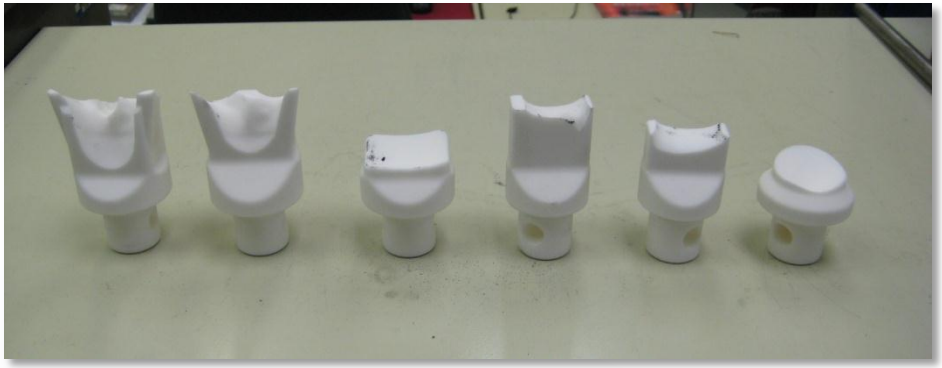
Produce New End Use Part

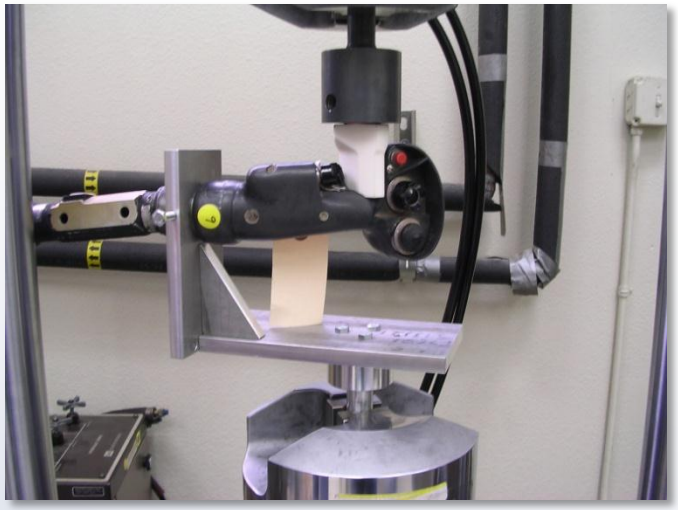
- Layup for Composite
- Forming for Sheet Metal



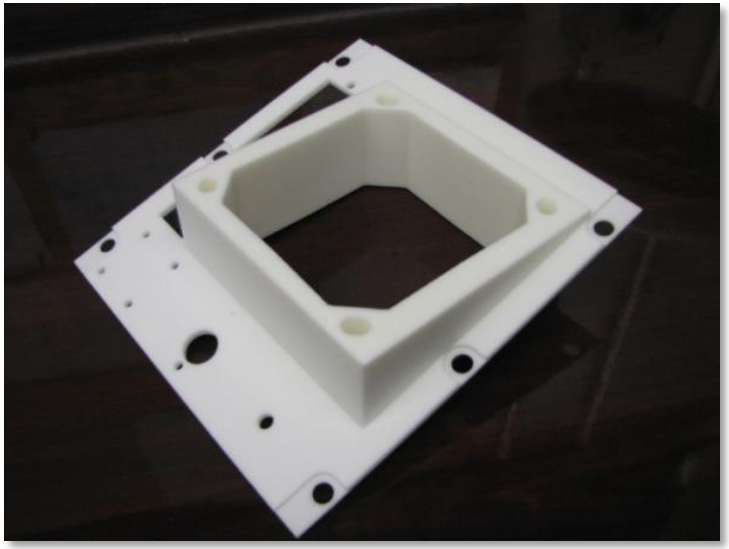
* Sacrificial

Rapid Prototyping and Testing





Custom Engineering Investigation Test Apparatus Parts.



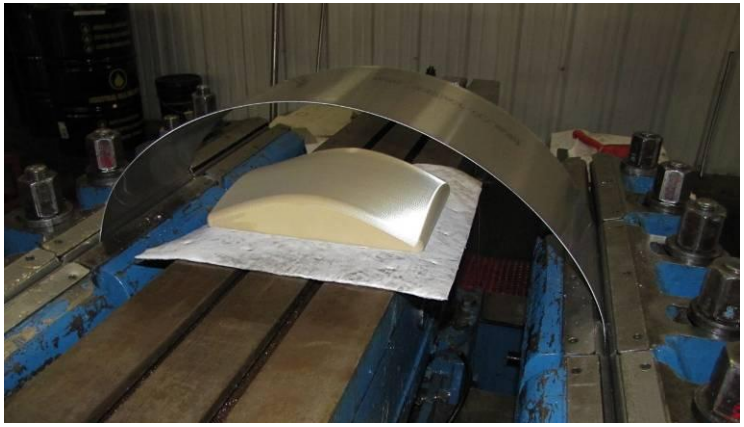
- **Form and fit check**
- **High impact to mission readiness – quick response**
- **Machining / manufacturing guide**
- **Turn-around time after CAD modeling: 1-2 days**

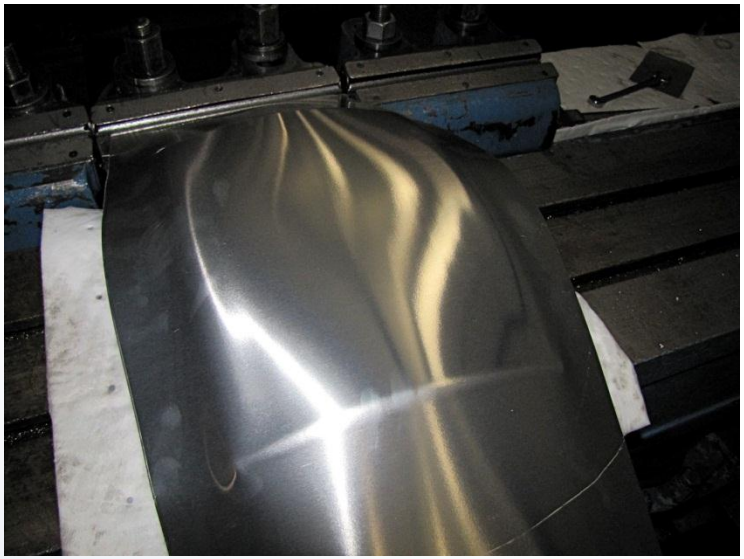
Sheet Metal Press Form Tooling

- **Demonstrated Applications**
  - Hydro forming
  - Rubber pad forming
- **Demonstrated Tooling**
  - Male & female, blow down tools
  - Pressure Intensifiers
  - Matched male & female tools
  - Backfilled tools
- **Demonstrated Conditions**
  - Range of alloys and thickness tested
  - Demonstrated forming pressures up to 10KSI
  - Variety of tools >100 cycles, some >500 cycles
  - Large jointed tools have been tested
- **Tooling Example**
  - $200 material, 8-hour build

Sheet Metal Stretch Form Tooling

- **Tool Details**
  - Size 10” x 13” x 2.5”
  - 2” crown w/ multiple contours
  - Tool material – ULTEM 9085
- **Successfully Formed**
  - Alloy 2024-0
  - Thickness 0.050” up to 0.100”
- **Run 10 times successfully**
- **Notes**
  - Surface pressures are minimal
  - Tool can be optimized to minimize build times and cost
  - PC and ABS (CF) are viable alternate materials depending on alloy, thickness and tool build styles
  - Larger size tools being tested with ORNL





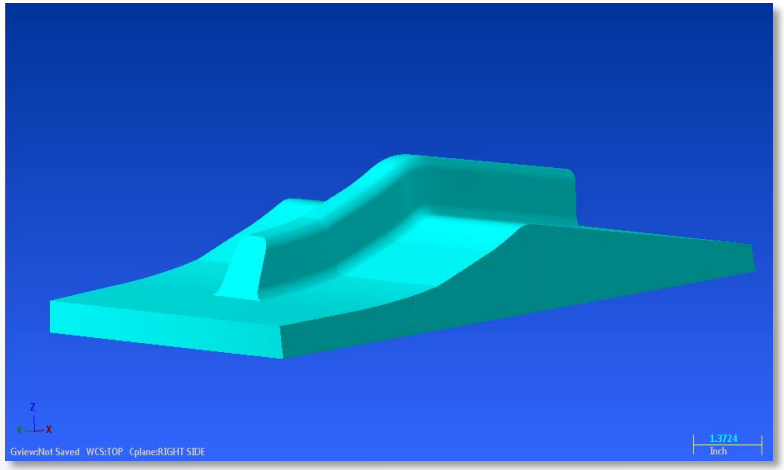
Rapid Composite Tooling

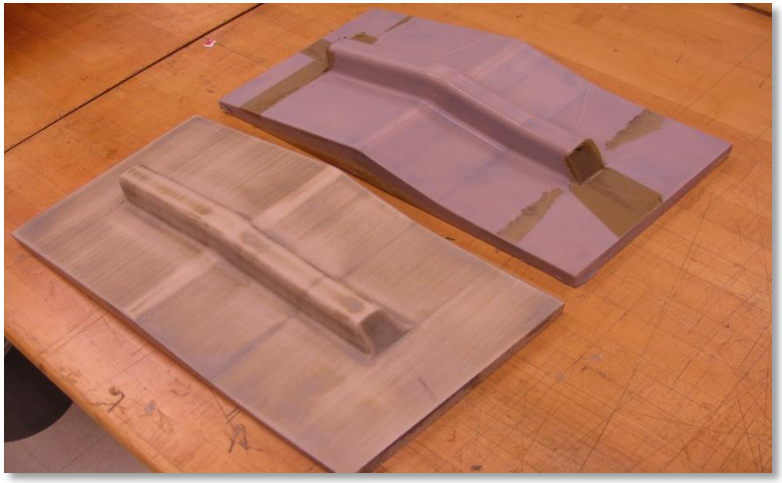
- **Traditional Composite Repair Sequence**
  - Serial process
    - Splash > mold > tool > part
    - Difficult to determine cause of fit issues
  - Lack of tech data
  - Artisan driven process
  - Condition of old part is critical because it will drive tool definition
  - Need to reduce touch labor for developing composite tooling
- **Composite Repair – Digital Tools**
  - Emerging work force using CAD tools
  - Combine multiple forms of data to derive desired part definition
  - The entire repair tool stream can be digitally mastered
  - Allows for solid model inspection to check fit

- **Constraints**
  - Tool & Part Size Vs. Build Volume
    - If AM machine build volume too small for the part in question, manual tooling methods used
  - Known CTE for AM built autoclave-able tools
    - 350ºF and 100 psig

Rapid Composite Tooling

Fused Deposition Modeling (FDM) 3D Printed Tooling





- Can be printed from a 3D model generated from laser scan of actual component.
- Tool printed with polyphenylsulfone (PPSF), covered with a layer of paste adhesive to fill in inconsistencies and wrapped with Teflon tape (for a sealed releasable surface).

AV-8B Hard Landing

RECENT CASE STUDY IN BENEFITS OF AM

HOVER STABILIZATION AT 20 FT.

AV-8B Hard Landing

LANDING APPROACH

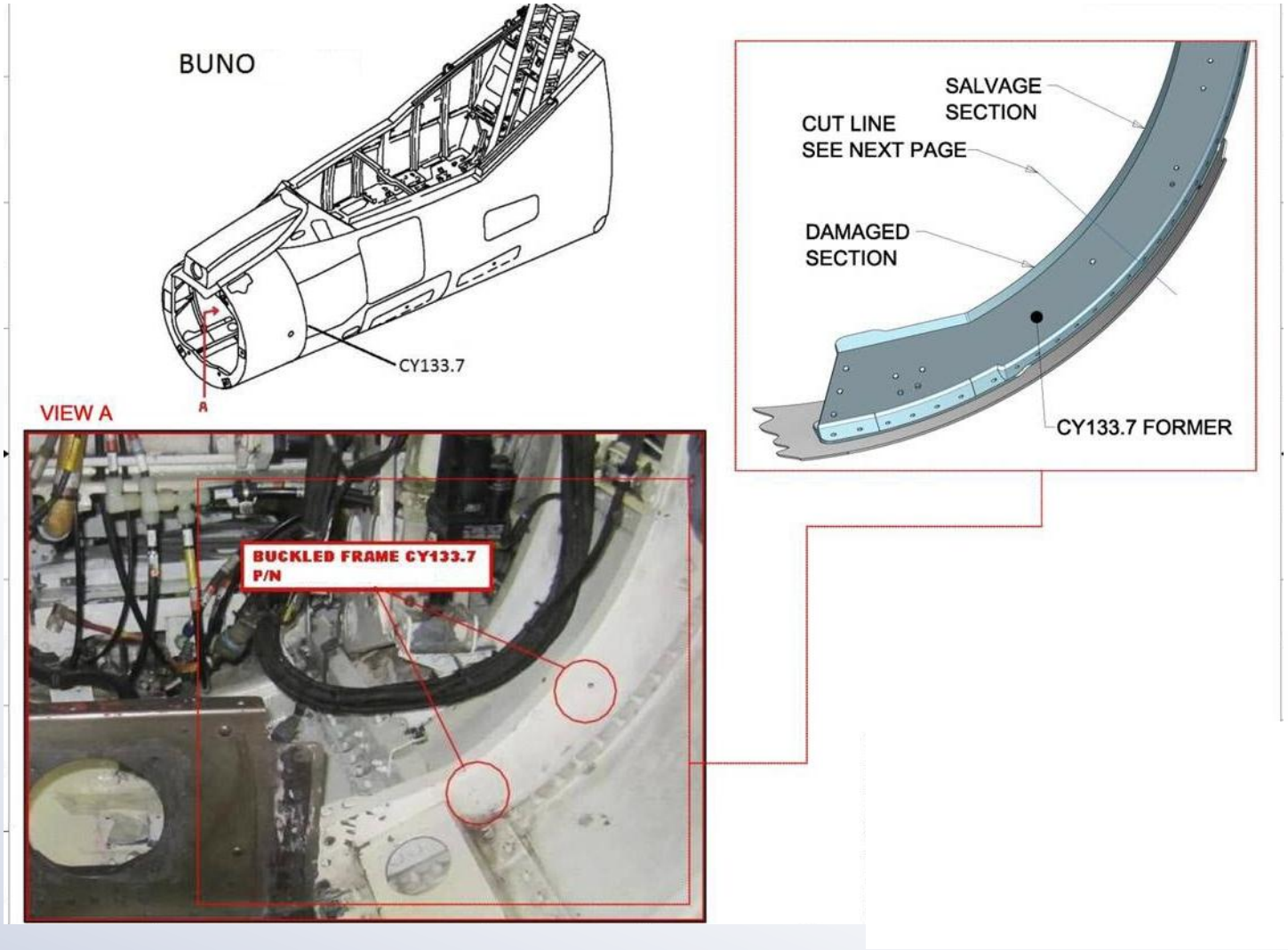
AV-8B Hard Landing

NOSE CONE ON SUPPORT

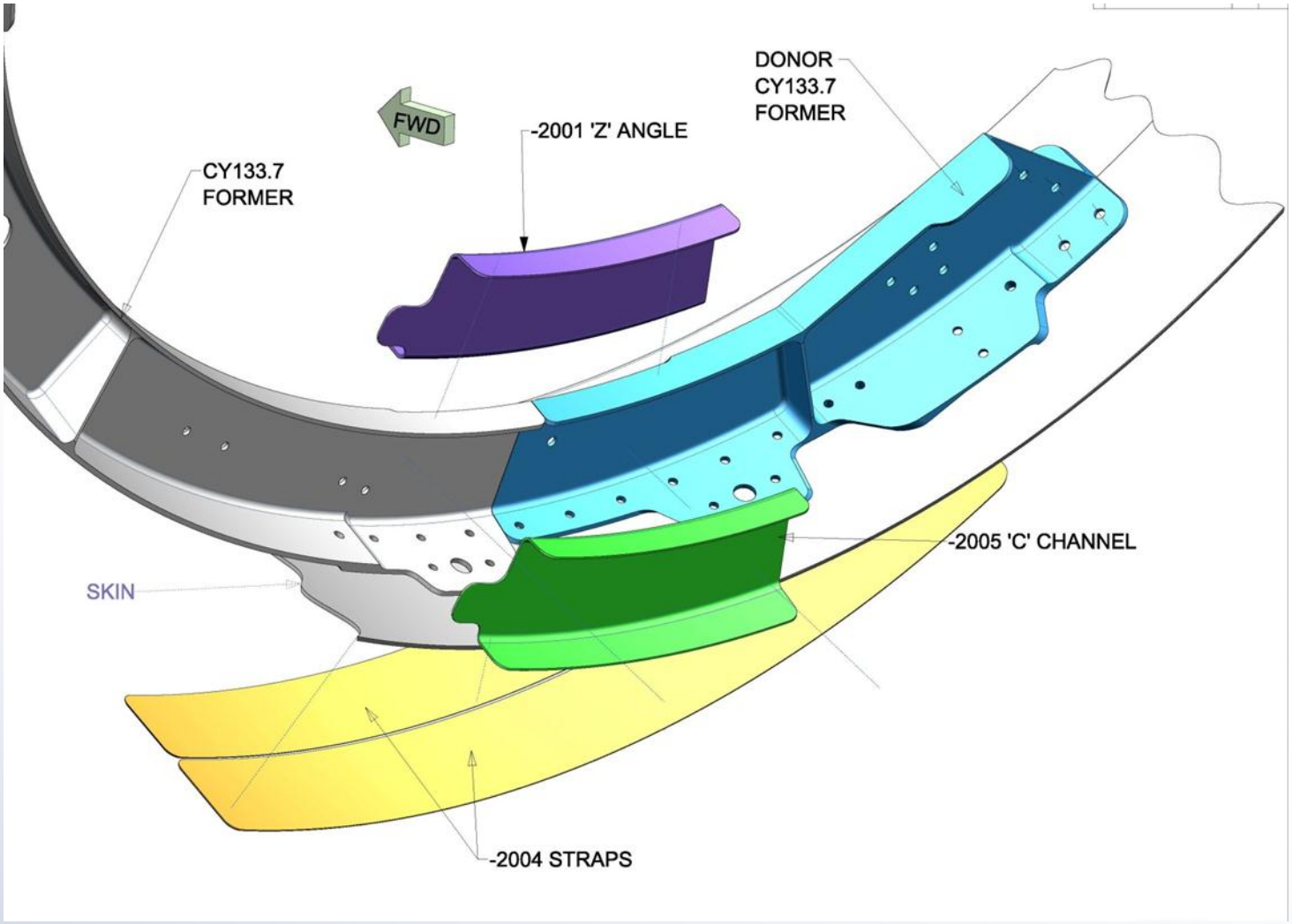
AV-8B Hard Landing

NOSE CONE BOUNCE BACK

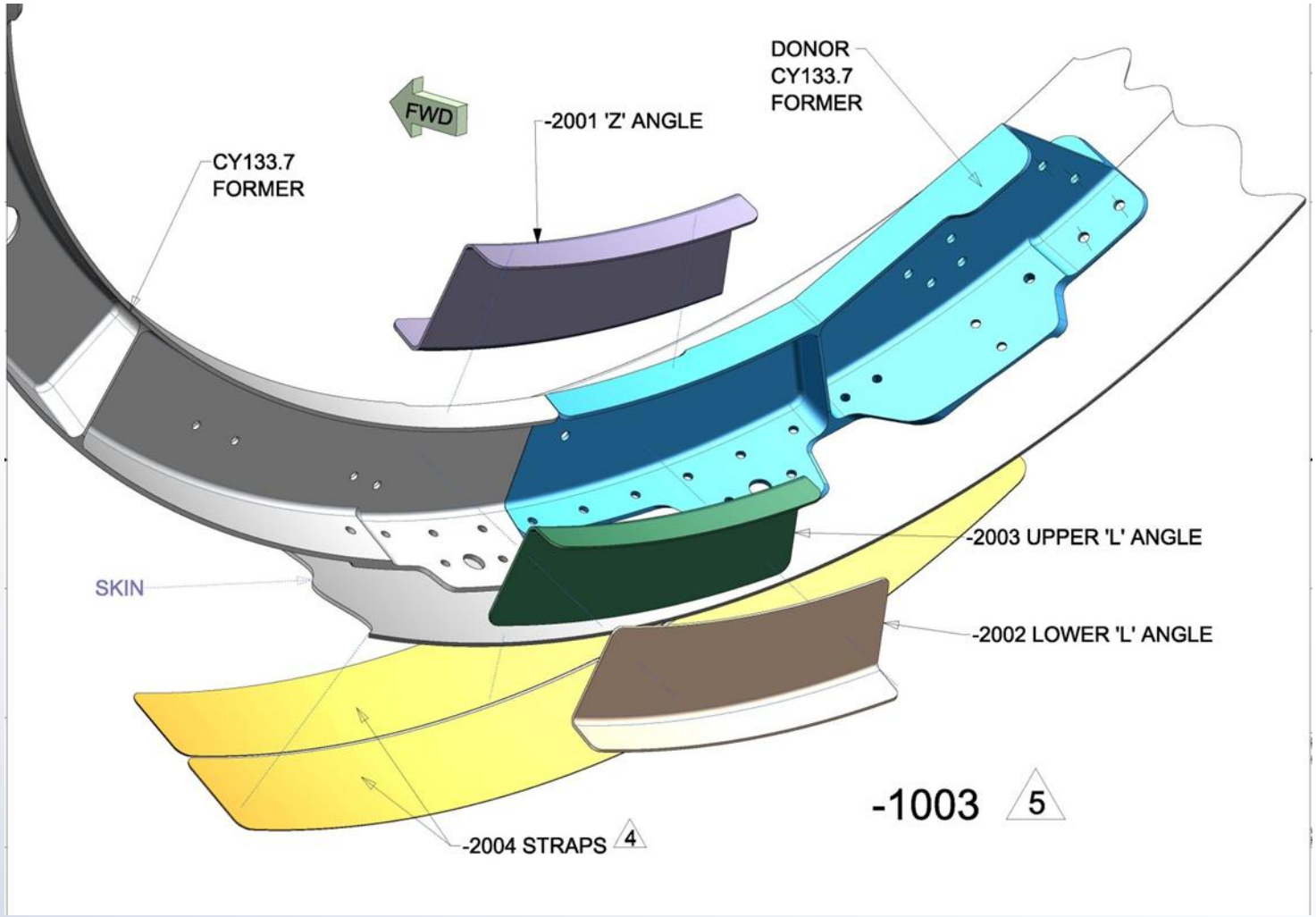
AV-8B Hard Landing - Design



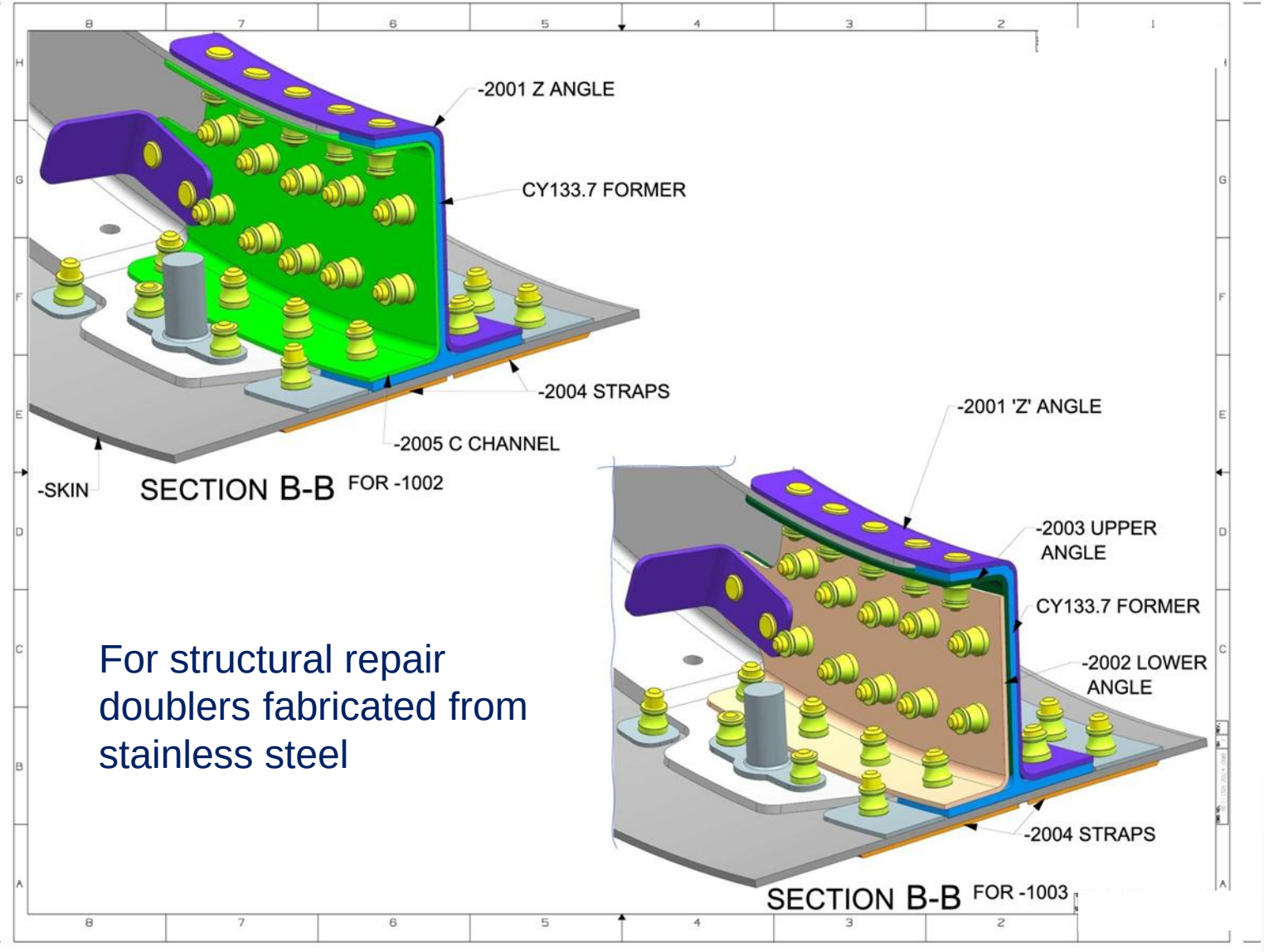
AV-8B Hard Landing - Design



AV-8B Hard Landing - Design

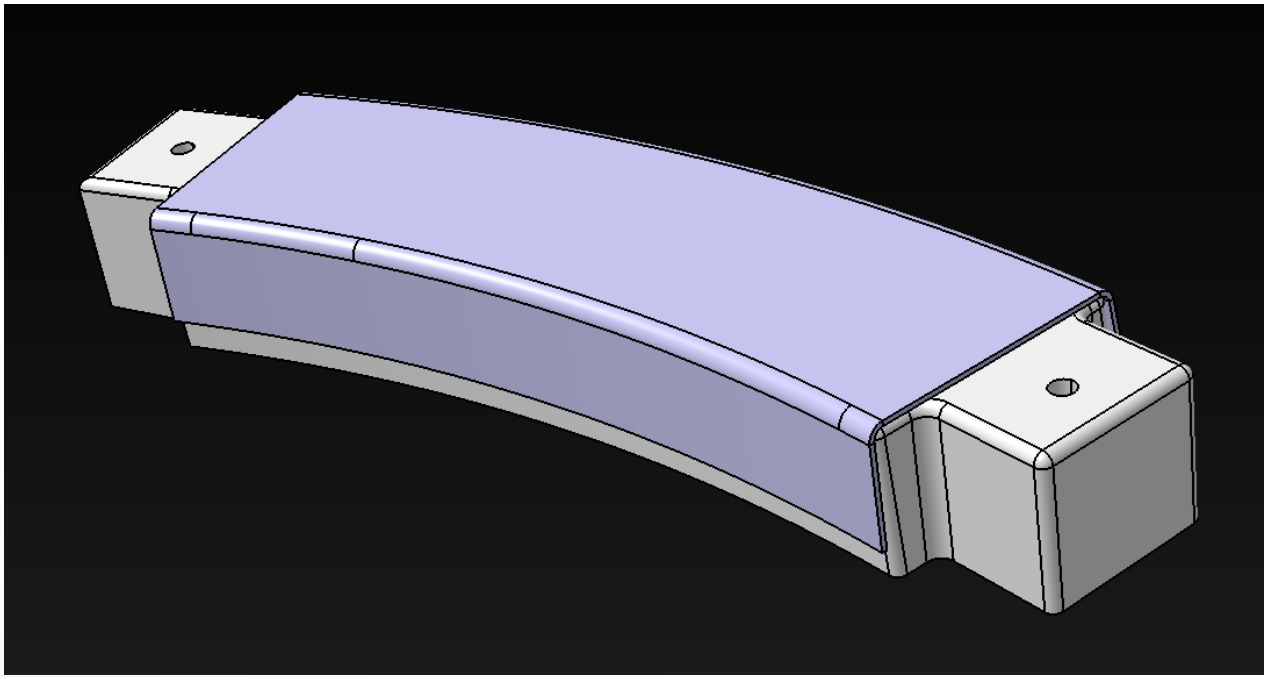


AV-8B Hard Landing - Design



For structural repair doublers fabricated from stainless steel

AV-8B Hard Landing - Tooling

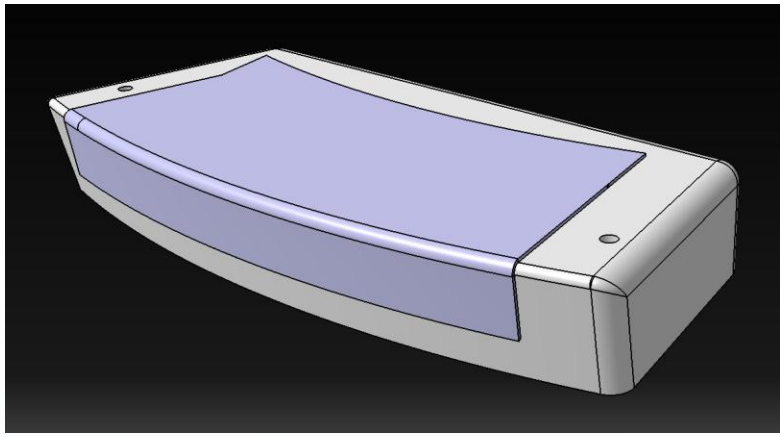


C & L Block Tool & Part

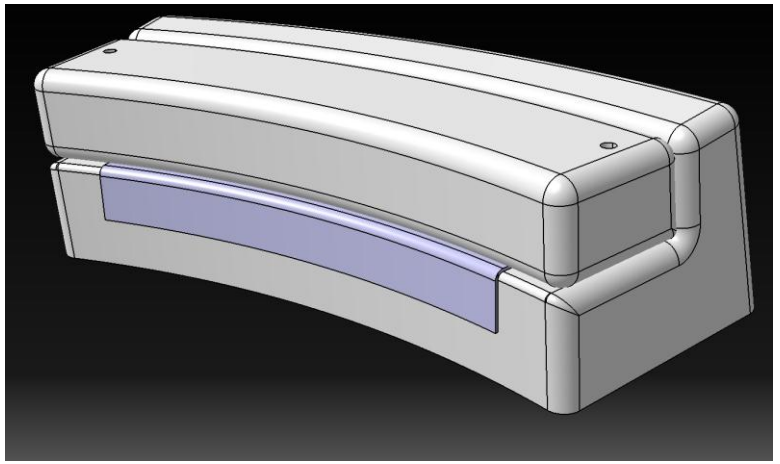
Part Forming

- Form three C Channels
- Cut two to form the Upper and Lower L Angle parts
- Retain third for C Channel
  - C Channel subsequently abandoned due to tolerance stack-up issues that would have negatively impacted shipboard repair
- Polycarbonate, FORTUS 900mc

AV-8B Hard Landing - Tooling



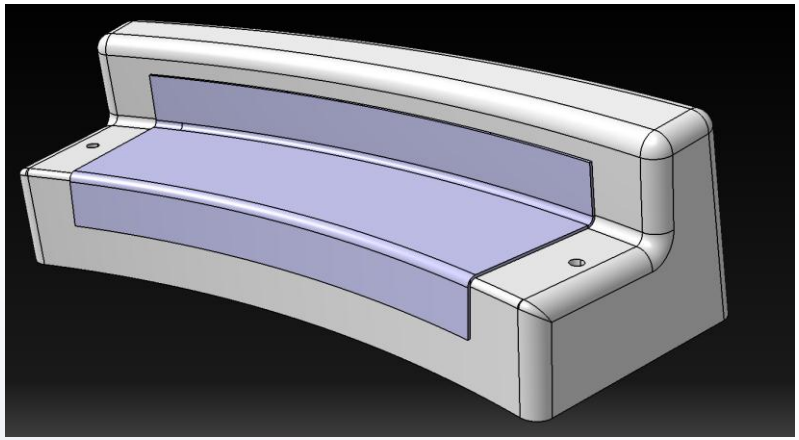
Z Block Stage 1



Z Block Stage 2 with Cover

Part Forming (Tabs Not Shown)

- Form upper lip using Stage 1 block
- Reverse part and place in Stage 2 block
- Attach cover block
- Form lower lip
- Polycarbonate, FORTUS 400mc



Z Block Stage 2

AV-8B Hard Landing

TIME LINE

- 07 JUNE 14
  - Controlled Hard Landing
- 25 JUNE (Wednesday)
  - Receive OEM solid model of damaged frame
  - Begin repair & tool design
- 26 JUNE (Thursday)
  - Form block designs complete
  - Begin AM builds at ~1700
- 27 JUNE (Friday)
  - Design & produce flat patterns
  - AM tool build parts complete
- 28 JUNE (Saturday)
  - Form C, L & Z doublers using rubber & bladder presses
  - Begin heat treat
- 30 JUNE (Monday)
  - Paint 1st set
  - Manufacture 2nd set backup parts
  - Heat treat 2nd set on second shift
- 01 JULY (Tuesday)
  - Paint 2nd set
- 02 JULY (Wednesday)
  - Deliver finished parts to FST

3D SOLID CAD MODELING AND AM MADE THE ONE WEEK TURN AROUND POSSIBLE.

Closing Comments

- Aviation Maintenance faces unique challenges
  - Aging infrastructure, Obsolescence issues, Service Life Extensions, Accelerated OPTEMPO
  - Mandate to reduce Total Operating Costs of existing platforms while at the same time introducing new platforms
- New technologies (AM and others) will:
  - Improve maintenance processes & procedures
  - Positively impact availability, reliability, & maintainability
- Increased exposure to new technologies in the workforce creates new innovative opportunities and ideas
- Expanded build volumes, lower cost materials and faster through-put needed for expanded use of AM in the manufacture of large air vehicle parts
  - BAAM (ORNL)
  - Sheet metal tooling applications
  - Composite tooling applications
- AM, 3D digital data, PLM enterprise software and connectivity will increase collaboration across FRC's, competencies and disciplines
- Prepares DoD Sustainment Community for a future of weapon systems built with increasing AM technology
- Encourage collaboration within DoD services and with academia & industry to move sustainment technologies forward
- FRC-E, FRC-SW & FRC-SE are designated Navy Federal Laboratories
  - Provides framework for collaboration (ongoing & future)
  - Cooperative Research & Development Agreements (CRADA) and Educational Partnership Agreements (EPA)

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QUESTIONS?